ISGAN/SIRFN International Smart Grid Workshop

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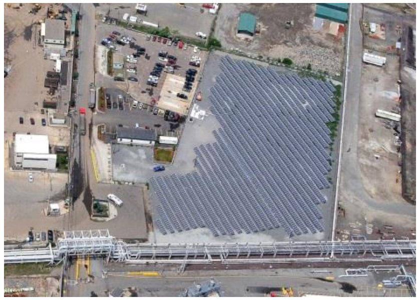
Agenda

- **National Grid's Solar Phase I Program**
- **Haverhill, MA Advanced Inverter Site Tests and Lessons Learned**
- **National Grid's Solar Phase II Program**
- **MA Technical Standards Review Group (TSRG)**
- **IEEE P1547 Updates**

Phase I Solar

Waltham* – 225 kW

Sutton – 983 kW



Everett – 605 kW

Revere – 750 kW

Dorchester – 1250 kW

Haverhill – 1016 kW

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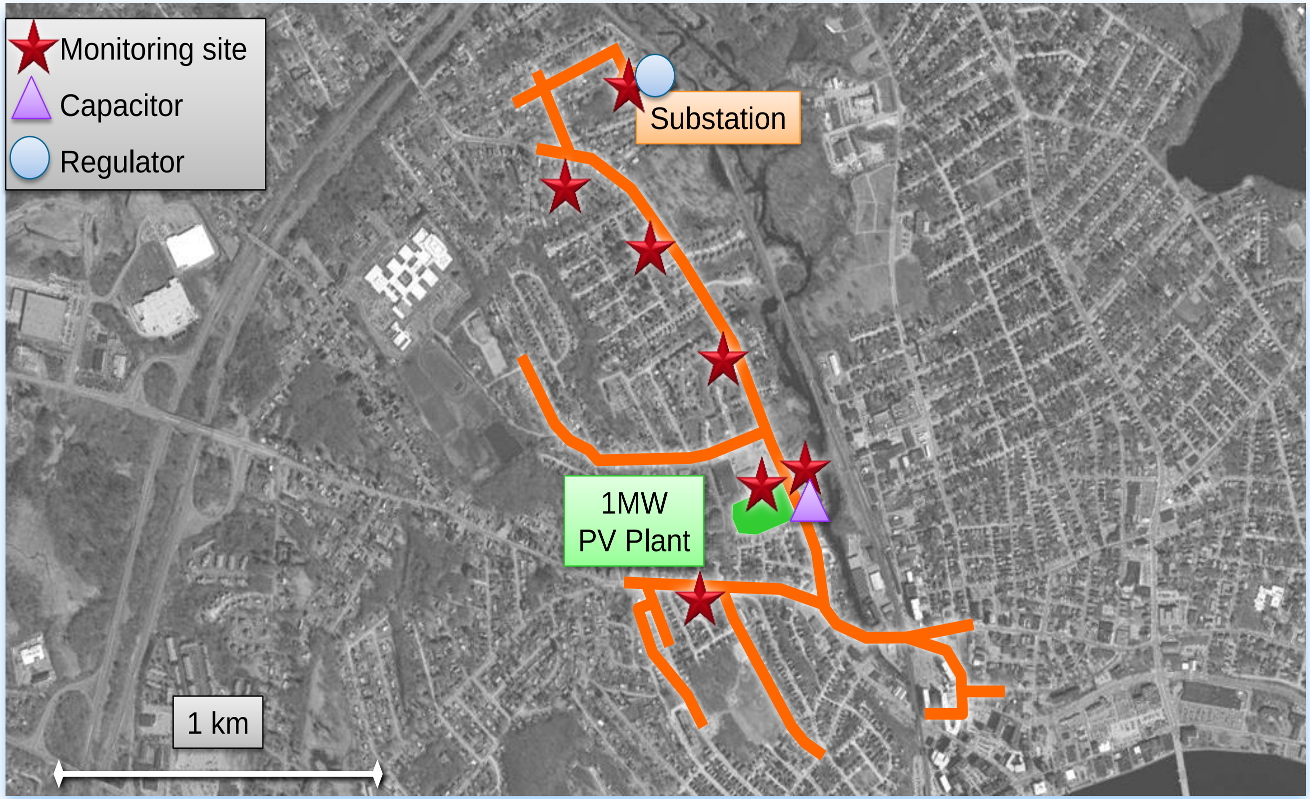
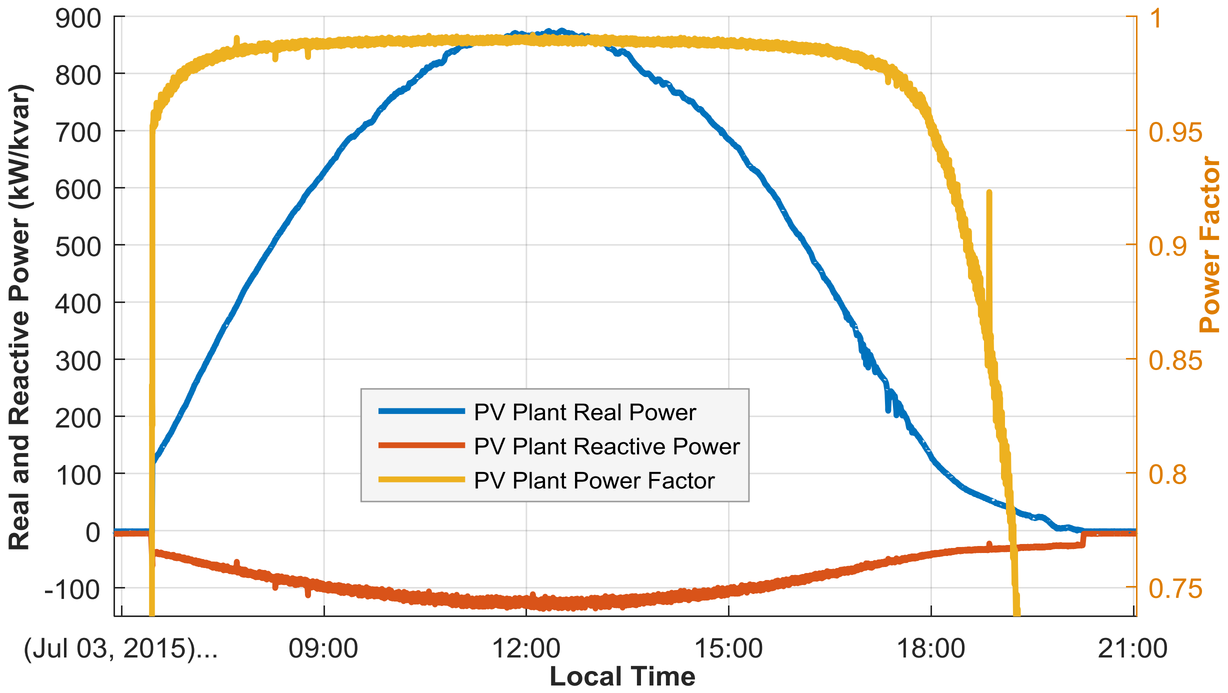
Haverhill, MA Advanced Inverter Testing



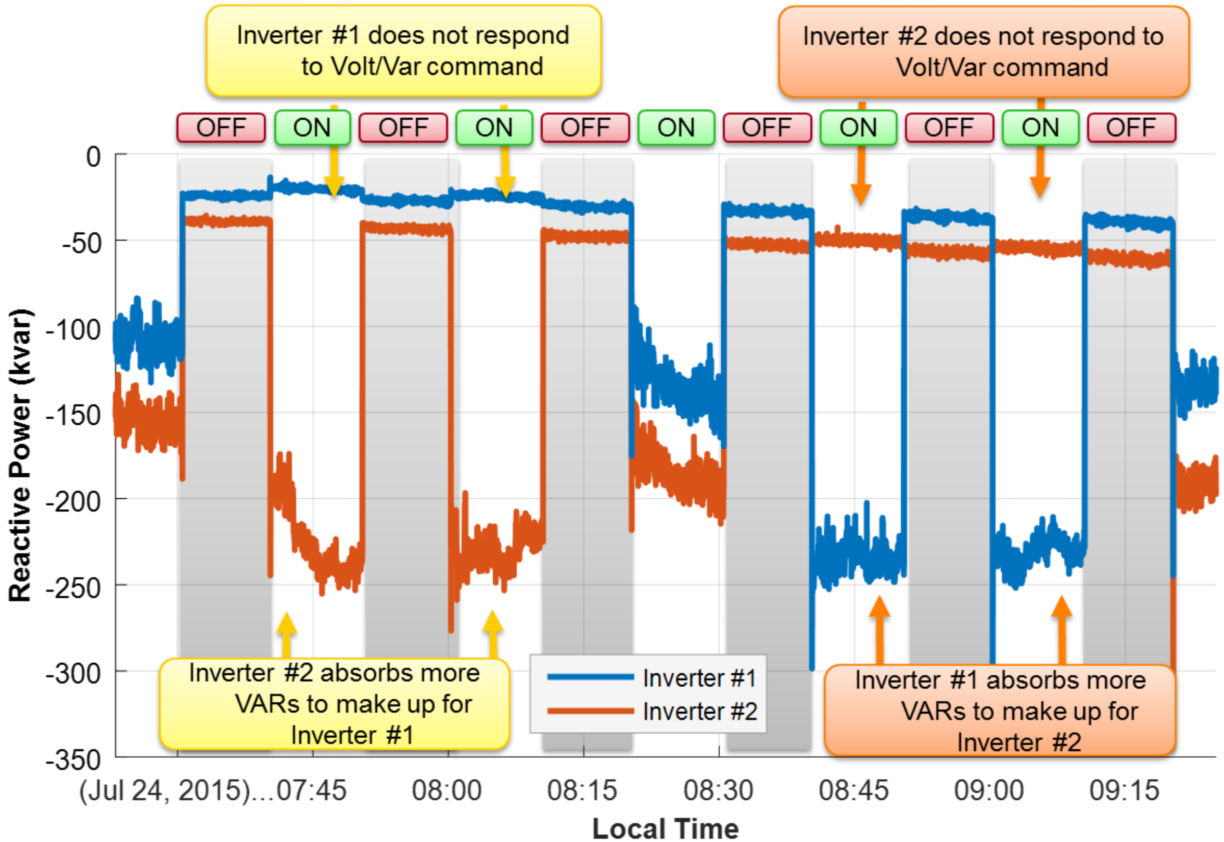
Map of Haverhill feeder and monitoring locations

Real and reactive power generation



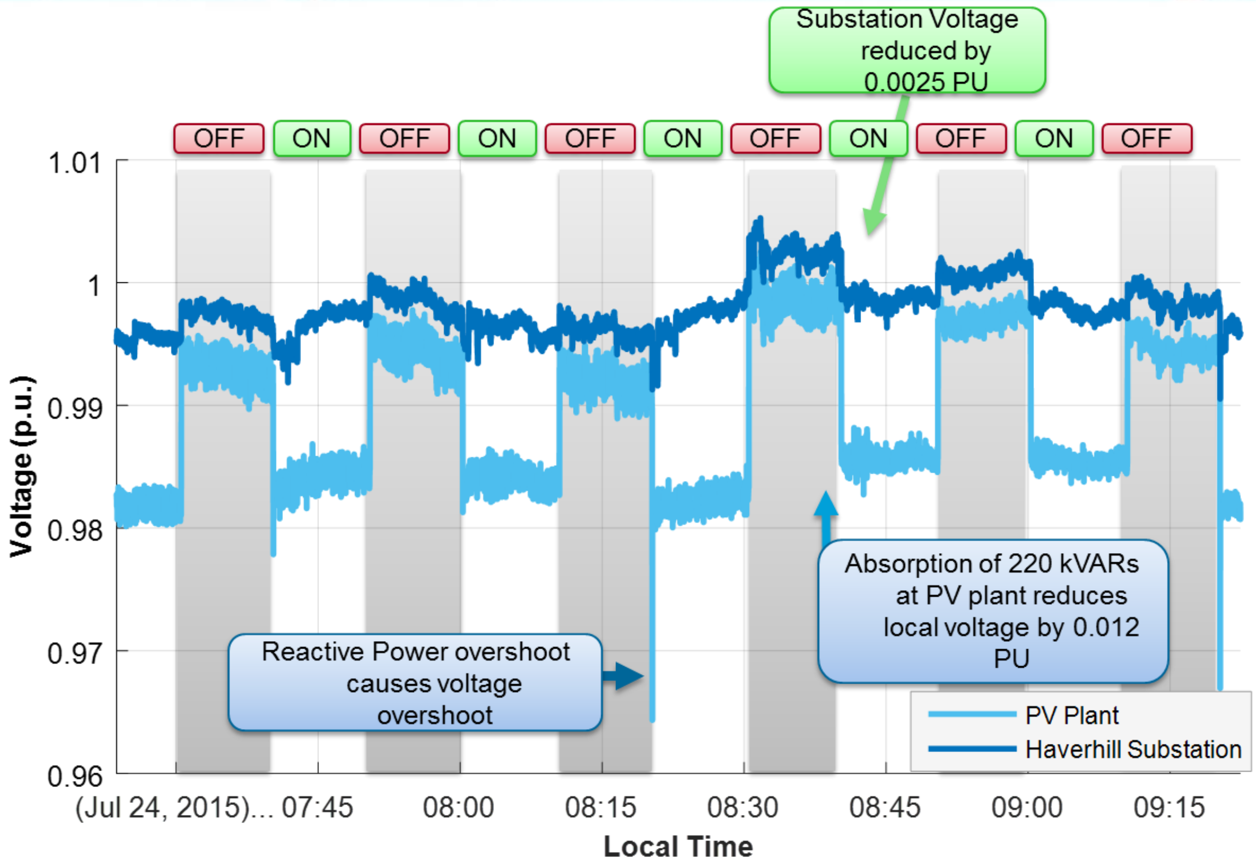
- More reactive power is absorbed by the inverter as the power increases throughout the day.
- The maximum reactive power absorbed by the inverter is 135 kvar. Although the reactive power changes throughout the day, the power factor is above 0.98 for most of the day.

10 mins ON/OFF Volt/VAR test



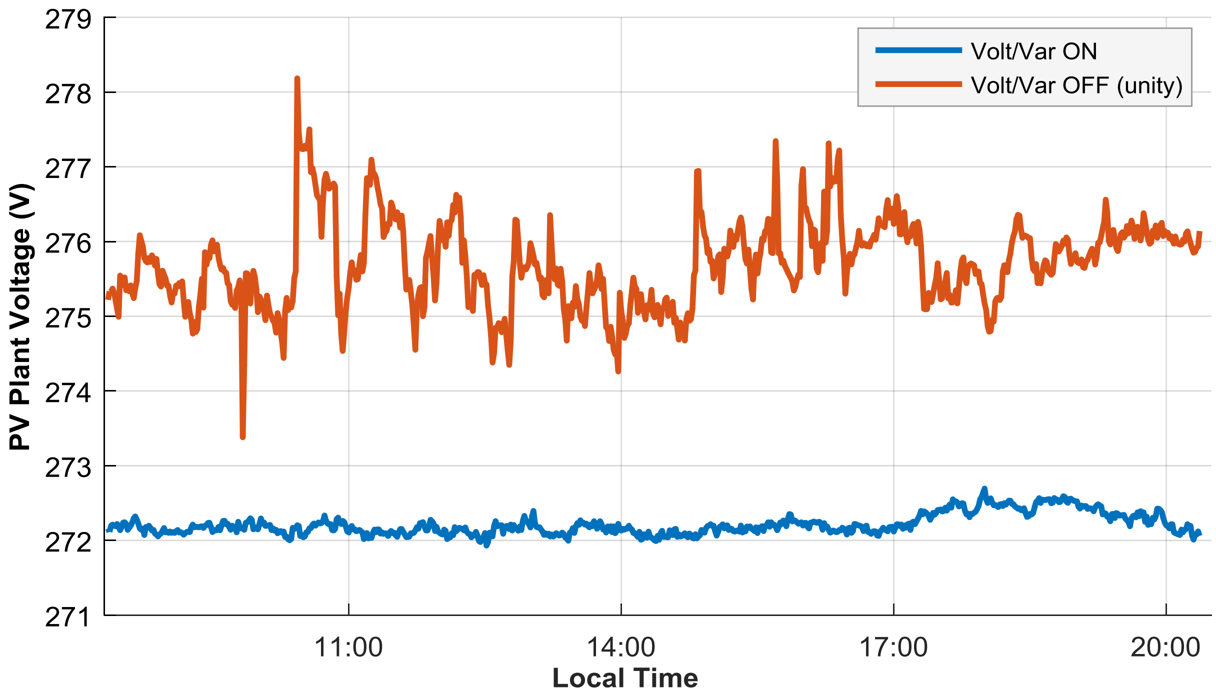
Occasionally, one of the inverters will not respond to the command, and continue operating at close to unity power factor. At 8:20 am, both inverters respond to the volt/var command. However, at 7:30 and 8:00 am, inverter #1 does not respond to the command, and inverter #2 absorbs more vars to compensate. This situation is reversed at 8:40 and 9:00 am, when inverter #2 does not respond, and inverter #1 absorbs more vars to compensate.

Impact of the Volt/VAR function on the substation and PV plant voltage



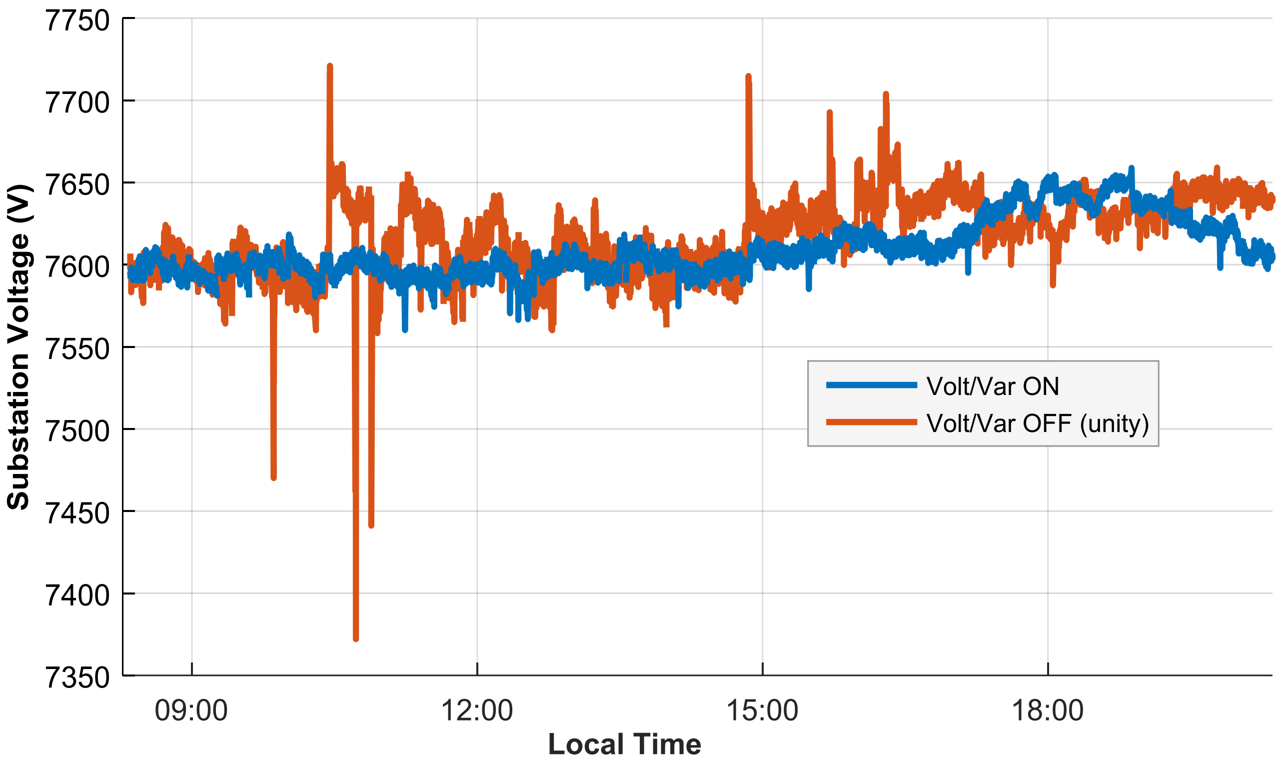
- The PV plant experienced an average voltage drop of 0.011 p.u. due to VAR absorption by the inverters each time the Volt/Var function was enabled.
- The substation experienced an average voltage drop of 0.0027 p.u. due to VAR absorption by the inverters for the same time period each time the function was enabled.

Impact of Volt/VAR on PV plant voltage variations



- The blue curve is the voltage at the PV plant throughout the day when the Volt/Var curve was enabled, and orange curve is the voltage at the PV plant on a similar day at unity operation.
- The variability is significantly lowered when the volt/var function is enabled.

Impact of Volt/VAR on substation voltage variations



The voltage during the day where the volt/var function is on is less variable than the day where the volt/var function is off.

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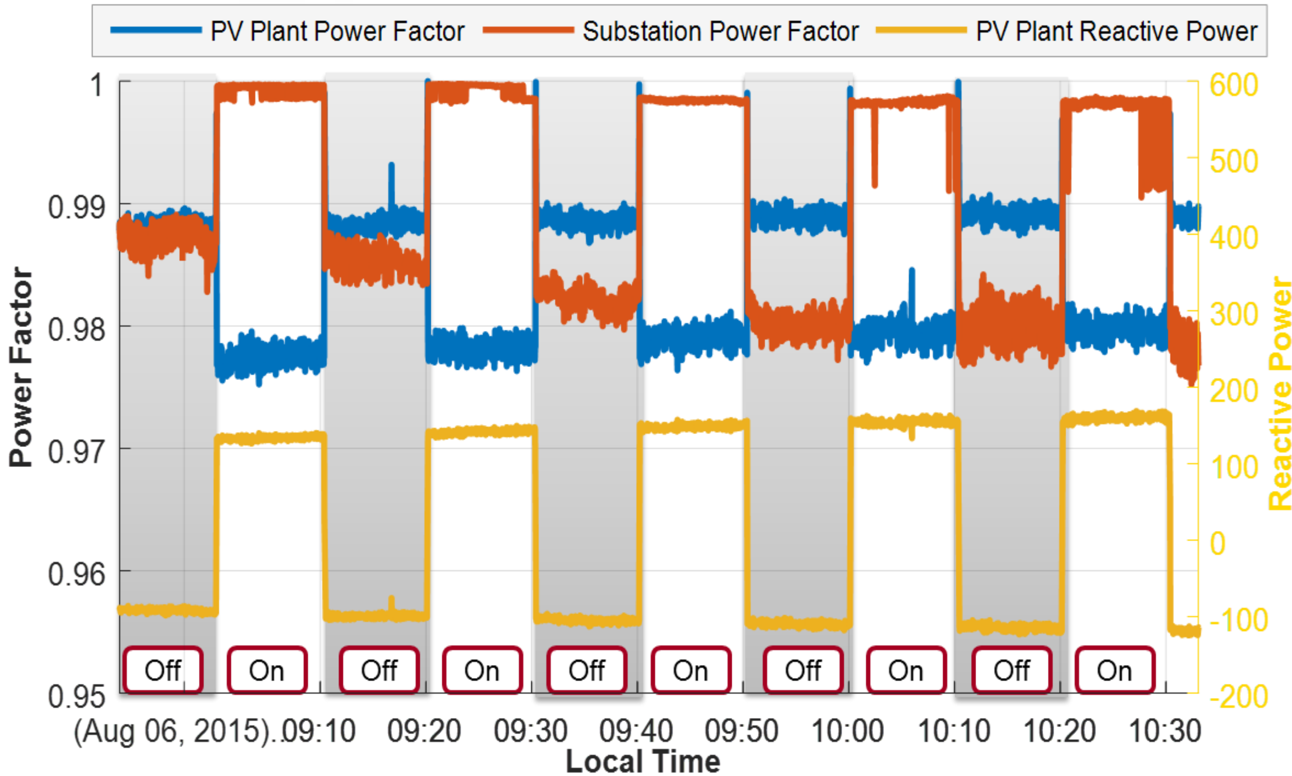
10 mins ON/OFF Constant PF Test



- When the PV Plant changes from close to unity to constant power factor, the reactive power changes from absorbing to injecting vars.
- This moves the PV plant power factor from 0.99 inductive to 0.98 capacitive. As a result of the constant power factor setting, the power factor at the substation is increased from 0.98 to 0.99.

Lessons Learned and Challenges

Volt/VAR function helps reduce the system voltage variations and increase the life-cycle of the load tap changers.

Challenge:

Still working with the inverter vendor to overcome the communication challenges.


National Grid’s Solar Phase II Program

Core team: Fouad Dagher, Justin Woodard, Jonathan Salsman, Tyler Krupa, Jorge Valenzuela, James Perkinson, Babak Enayati

Phase II Solar“ Integrate vs. Interconnect”

Purchase up to 20 MW’s of turn-key solar sites, implemented with advanced inverters

National Grid’s goal is to use these sites, to further solar development in the commonwealth through advanced technologies

- **Less Expensive Interconnection Costs**
- **Increase Penetration of PV per Feeder**
- **Lessons Learned**

Learn more about impacts of solar on areas by pre-selecting towns with:

- **High PV penetration feeders**
- **Lightly loaded feeders**
- **Heavy loaded feeders**

Solar Phase II Update

Four sites interconnected

Auburn Rd Millbury – 650 kW

Oxford Rd Charlton – 650 kW

Groton Road Shirley– 1 MW

Richardson Drive Attleboro – 1MW

Sites constructed

Boutilier Rd Leicester – 650 kW

Kelly Rd Sturbridge (1) – 1 MW

Kelly Rd Sturbridge (2) – 1 MW

Sites under construction:

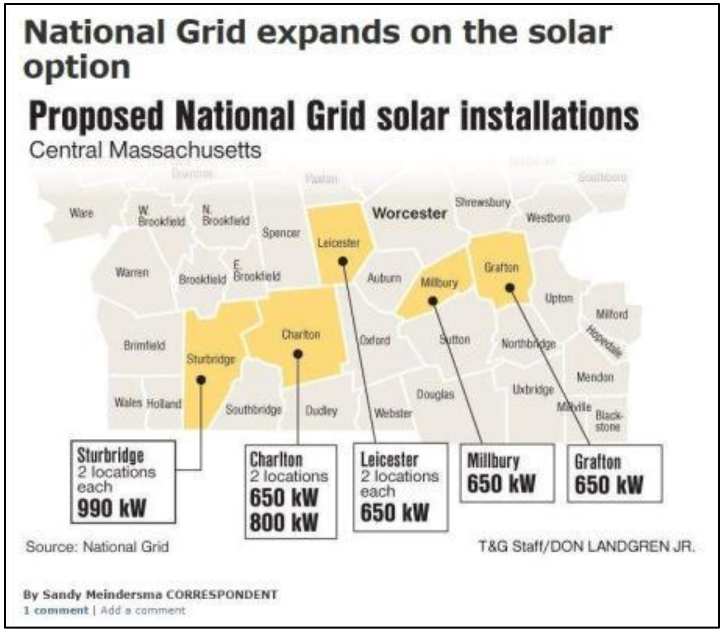
Carpenter Hill Rd Charlton – 800 kW

Stafford St Leicester - 650 kW

Main St Dighton – 1MW

Old Upton Rd Grafton – 650 kW

Groton Rd Ayer – 1MW



Advanced Functionalities

Functionality	Modes	Description
Active Power Control	Real Power Curtailment	Ability to limit the active power production of the PV site to a value below its potential
Active Power Control	Ramp Rate Control	Ability to limit the rate of change in magnitude of active power supplied
Reactive Power Control	Fixed Power Factor: Pffixed	Ability to maintain a power factor at the PV site's PCC by changing reactive power injection
Reactive Power Control	Fixed Reactive Set-point: Qfixed	Ability to inject a fixed amount of reactive power (percentage of nameplate) at the PCC
Reactive Power Control	Power factor compensation - Power factor/active power characteristic curve PF(P)	Ability to establish a Power Factor level at the PCC based on actual Active Power production
Reactive Power Control	Voltage Compensation - Reactive power/voltage characteristic curve Q(U)	Ability to inject Reactive Power at the PCC based on actual Voltage level
Reactive Power Control	Voltage Regulation – closed loop regulation of the voltage Ramp Rate Control	Ability to establish a Voltage level at the PCC by injecting Reactive Power. Ability to limit the rate of change in magnitude of reactive power supplied
Frequency Droop Response	Real Power Curtailment	Ability to curtail Active Power during higher than normal frequency at the PCC
Low Voltage Ride Through ("LVRT") & High Voltage Ride Through ("HVRT")	Ride Through or Modulated Power Output	Ability to configure the tripping of the PV site during Under and Over Voltage events at the PCC (beyond what UL1741 specifies)
Frequency Ride Through ("FRT")	Ride Through or Modulated Power Output	Ability to configure the tripping of the PV site during Under and Over Frequency events at the PCC (beyond what UL1741 specifies)

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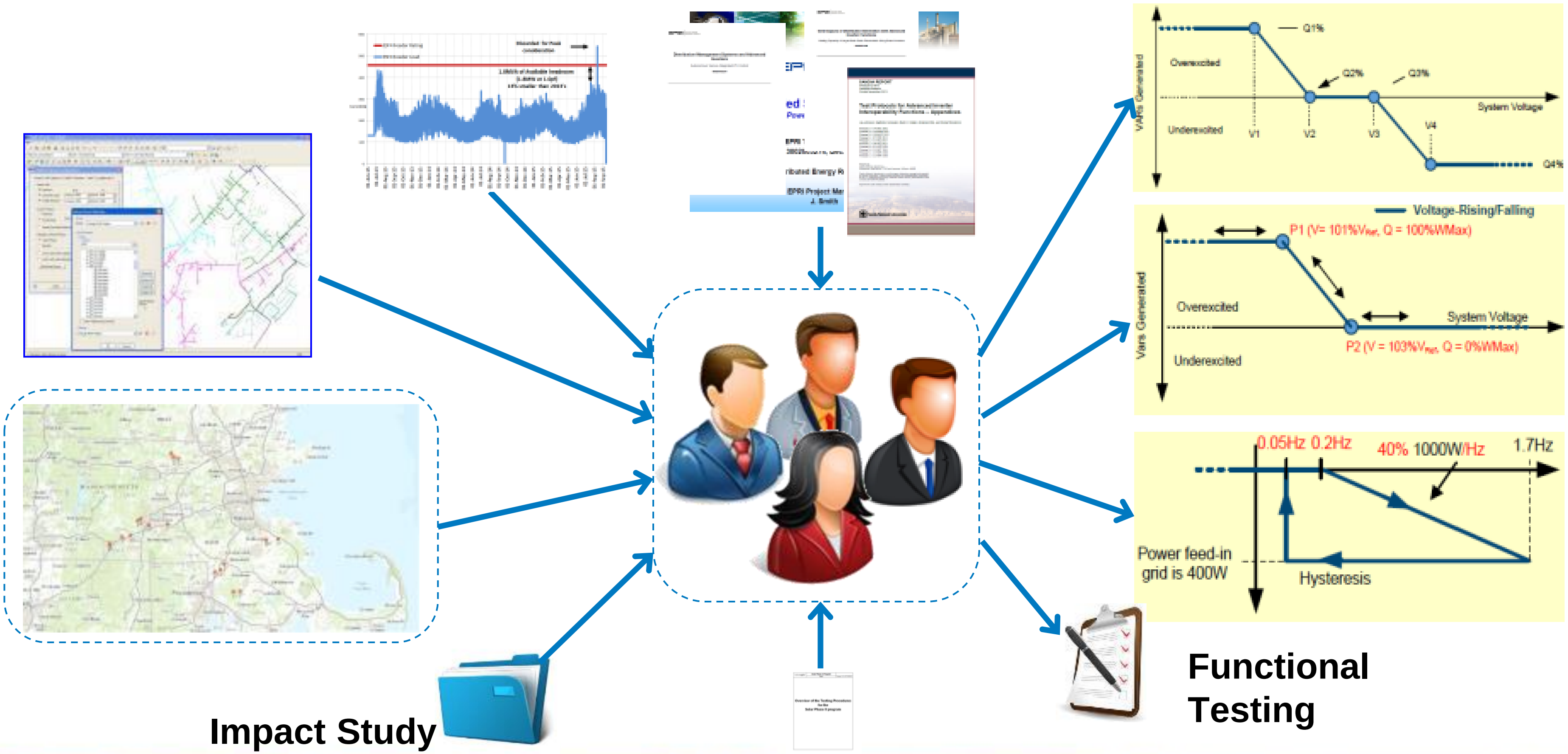
Each site is different

- Each site requires specific configuration settings based on the operational conditions in the area and the “purpose” of the site



MA Technical Standards Review Group (MA TSRG)

MA Technical Standards Review Group (MA TSRG)

The TSRG group was assembled through an agreement among the DG Working Group members. Details about this agreement can be found on page 30 of the *Proposed Changes to the Uniform Standards for Interconnecting Distributed Generation in **Massachusetts ****, the final report of the Distributed Generation Working Group (September 14, 2012).

*.http://massdg.raabassociates.org/Articles/Final%20MA%20DG%20WG%20Report%209-14-12.pdf

MA Technical Standards Review Group (MA TSRG)

Goals:

1. **Review the MA Utilities' interconnection guidelines**
2. **Increase the commonalities among utilities with regards to DG interconnection practices**
3. **Provide technical support for incoming MA interconnection challenges**

MA Technical Standards Review Group (MA TSRG)

Website:

https://sites.google.com/site/massdgic/home/interconnection/technical-standards-review-group

Membership:

Utility Members:

Chair: Babak Enayati, National Grid / 781-907-3242 / Babak.Enayati@nationalgrid.com

Michael Brigandi, Eversource West / Michael.Brigandi@eversource.com

Cynthia Janke, Eversource East / cynthia.janke@nu.com (alternate: Erik Morgan)

John Bonazoli, Unitil / bonazoli@unitil.com

Michael Porcaro, Michael.Porcaro@nationalgrid.com

Non-Utility Members:

Vice-Chair: Michael Conway, Borrego Solar / 978-610-2860 / mconway@borregosolar.com

Reid Sprite, Source One / 617-399-6152 / rsprite@s1inc.com

Richard Gross, State Government Representative rgross@ieee.org

Nancy Stevens, Director of Consumer Division, Massachusetts Department of Public Utilities (DPU)

How is TSRG involved in Smart Inverters' interconnections?

1) National Grid presents the Solar Phase II program status update at every TSRG meeting.

2) IEEE P1547 standard revision review. The TSRG team spends at least an hour at each meeting to review the proposed revisions to the IEEE P1547, which will allow integration of Advanced Generators.

IEEE 1547 Standard for Interconnecting Distributed Resources with Electric Power Systems

P1547 Chair Tom Basso
P1547 Secretary/Treasurer Charlie Vartanian
Vice Chairs (Central Desktop [CD] Subgroup Leaders)
John Berdner
Jim Daley
Babak Enayati
Mark Siira
IEEE SCC21 Liaison Mike Kipness,

IEEE SCC21 1547 Series of Standards*

IEEE Std 1547™(2003 and 2014 Amendment 1) Standard for Interconnecting Distributed Resources with Electric Power Systems

IEEE Std P1547™(full revision) Draft Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces

IEEE Std 1547.1™(2005 and 2015 Amendment 1) Standard for Conformance Tests Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems

IEEE Std P1547.1 (full revision) Draft Standard for Conformance Tests Procedures for Equipment Interconnecting Distributed Energy Resources with Electric Power Systems and Associated Interfaces

IEEE Std 1547.2™(2008) Application Guide for IEEE 1547 Standard for Interconnecting Distributed Resources with Electric Power Systems

IEEE Std 1547.3™(2007) Guide for Monitoring Information Exchange, and Control of Distributed Resources with Electric Power Systems

IEEE Std 1547.4™(2011) Guide for Design, Operation, and Integration of Distributed Resource Island Systems with Electric Power Systems

IEEE Std 1547.6™(2011) Recommended Practice for Interconnecting Distributed Resources with Electric Power Systems Distribution Secondary Networks

IEEE Std 1547.7™ (2013) Guide to Conducting Distribution Impact Studies for Distributed Resource Interconnection

IEEE Std P1547.8™ Draft Recommended Practice for Establishing Methods and Procedures that Provide Supplemental Support for Implementation Strategies for Expanded Use of IEEE Std 1547-2003

* Colored background designates IEEE published standard; clear background is draft standard work in progress.

1547: Interconnection Is The Focus

Distributed Energy Resource (DER) unit

Interconnection System

Note: P1547 full revision started in year 2015 is also addressing interoperability and interfaces

Area Electric Power System (EPS)

IEEE 1547

IS:

A Technical Standard – Functional Requirements For
- the interconnection itself
- the interconnection test

Technology neutral, e.g., does not specify particular equipment nor type

A single (whole) document of mandatory, uniform, universal, requirements that apply at the PCC or Point of DER Connection.

Should be sufficient for most installations.

IEEE 1547

Is NOT:

- a design handbook
- an application guide
- an interconnection agreement
- prescriptive, e.g., does not address DR self-protection, nor planning, designing, operating, or maintaining the Area EPS.

IEEE 1547.1 is:
Test Procedures for Conformance to1547

IEEE Std 1547a – Amendment 1, May 2014

(Amendment 1: revisions to 4.1.1, 4.2.3, and 4.2.4)

4.1.1 Voltage Regulation

… DER allowed to change its output of active and reactive power.

4.2.3 (Response to abnormal grid …) Voltage

…. DER allowed to "ride through" abnormalities of grid voltage;

… grid and DER operators can mutually agree to other voltage trip and clearing time settings

4.2.4 (Response to abnormal grid …) Frequency

… DER allowed to provide modulated power output as a function of frequency

… … grid and DER operators can mutually agree to other frequency trip and clearing time settings

P1547 New Requirements for Ride Through (Work In Progress)

Three Categories of DER Operational Responses to Support the Grid -- Based on Local and Farther Reaching Grid Requirements and DER

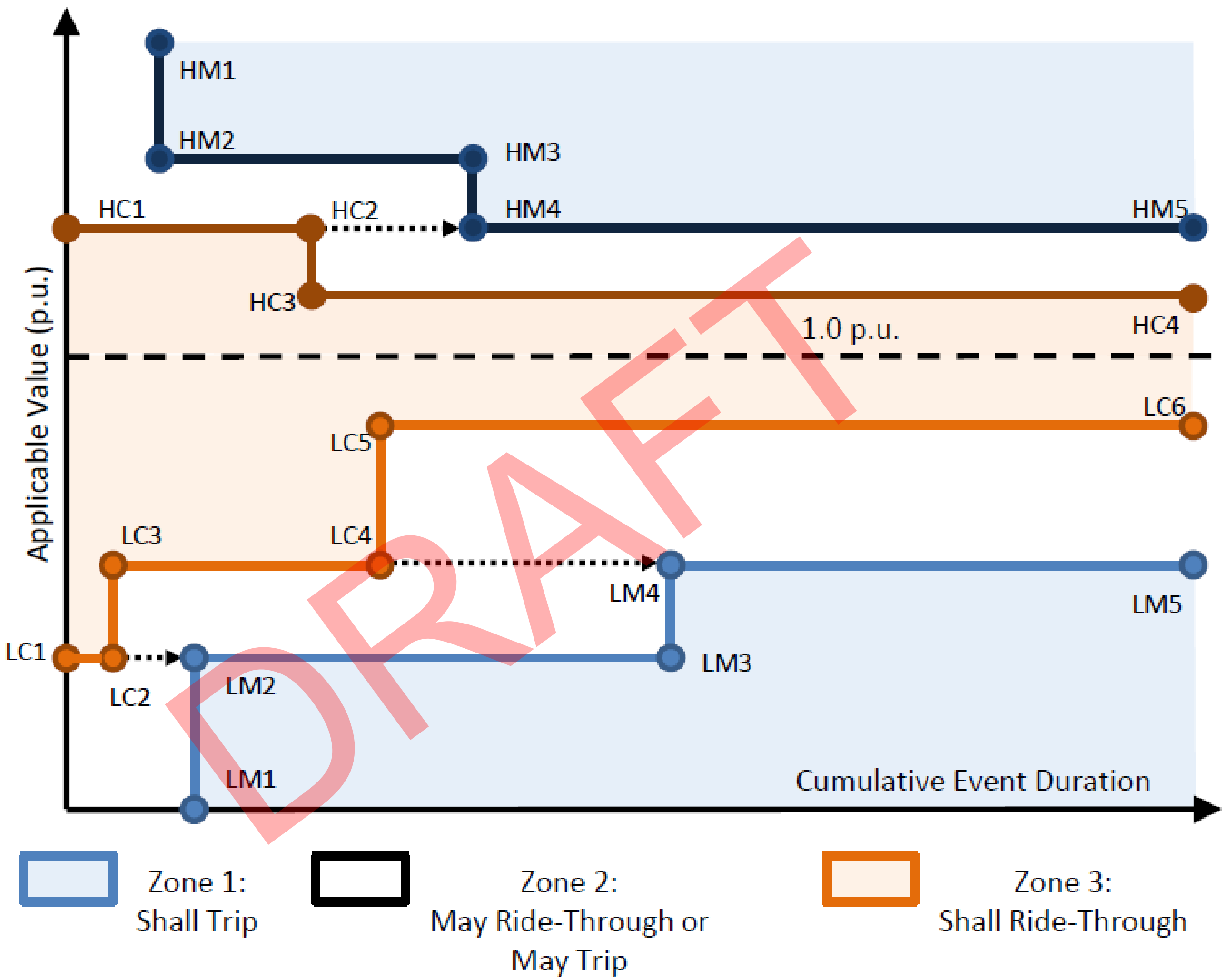
Requirement	Category	Foundation	Justification
Voltage Ride-Through	Category I	German grid code for medium voltage-connected synchronous generator-based DER	• *Essential* bulk system needs. • Attainable by all state-of-the-art DER technologies.
	Category II	NERC PRC-024-2 but w/o stability exception, extended LVRT duration for 65-88% V_{nom} ➢ based on EPRI White Paper (May 2015)	• *All* bulk system needs. • Coordinated with existing reliability standards. • Considering fault-induced delayed voltage recovery.
	Category III	CA Rule 21 and Hawaii, minor modifications	• All bulk system needs. • Considering fault-induced delayed voltage recovery. • Distribution system operation.
Frequency Ride-Through	All Categories (harmonized)	CA Rule 21 and Hawaii, exceeds PRC-024-2 ➢ based on EPRI White Paper (May 2015)	• All bulk system needs. • Low inertia grids.

P1547 New Requirements for Ride Through (work in progress)

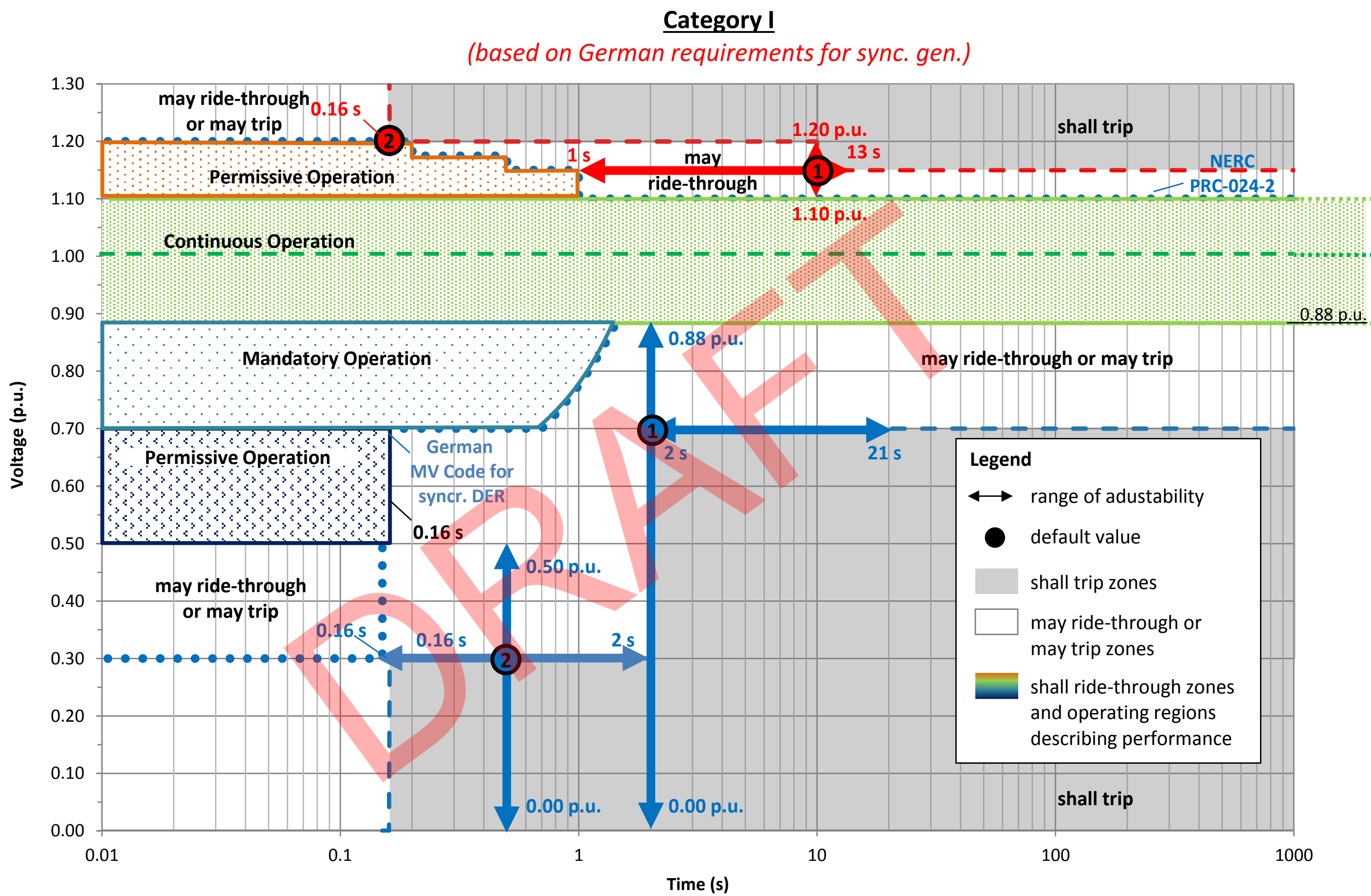
Ride through operation and tripping zones defined:

- **Continuous operation** – Area EPS normal operating voltage range
- **Mandatory operation** – DER shall remain operating for area EPS reduced voltage up to a second or so
- **Permissive Operation** – DER may operate for area EPS further reduced voltage or small overvoltages for up to 10 cycles
- **Momentary Cessation** – DER stops producing at area EPS low voltages but does not trip –
- **Shall trip** - For area EPS overvoltages and undervoltages that extend beyond 10 cycles to 2 seconds or more

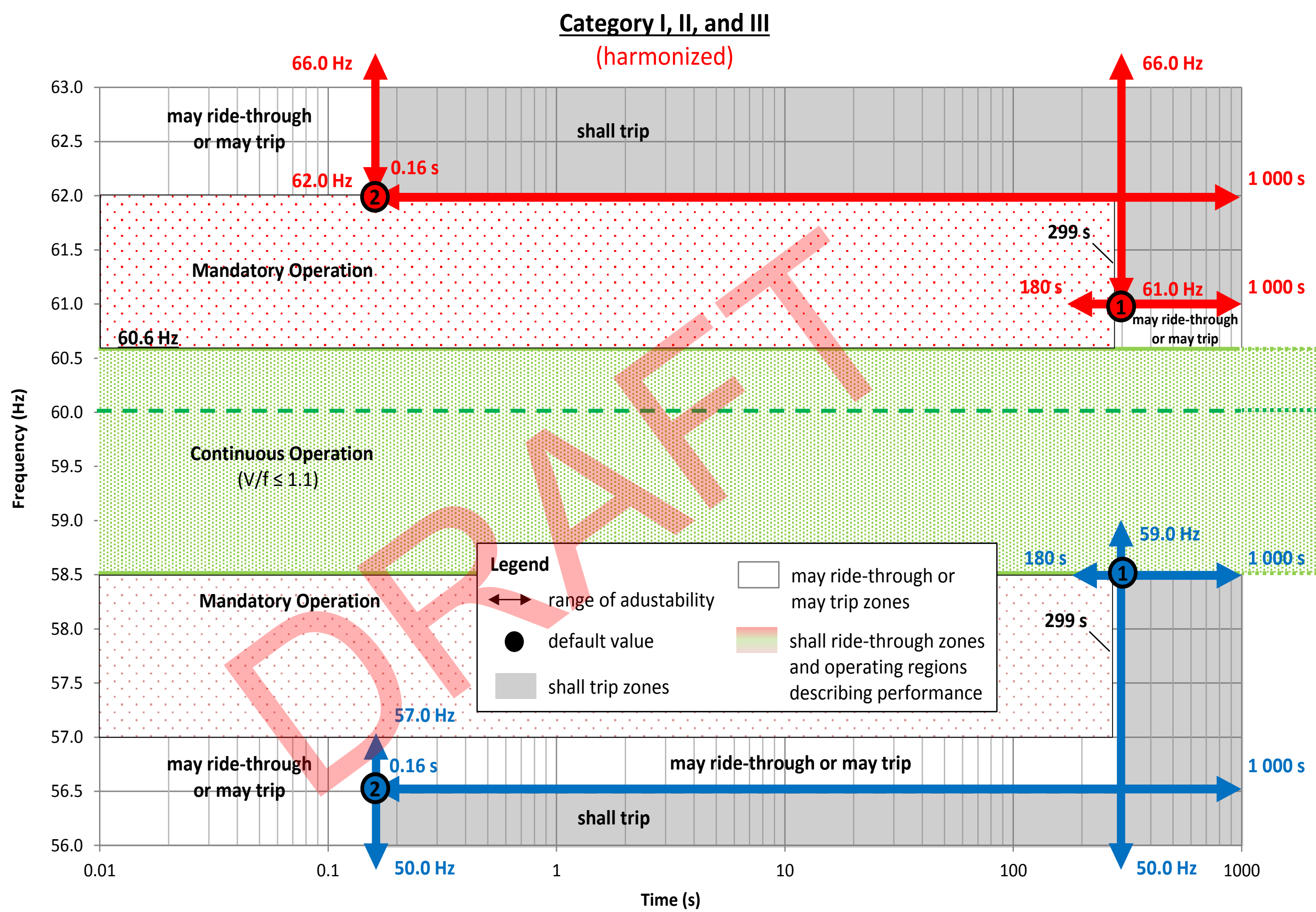
P1547 New Requirements for Ride Through (work in progress)



P1547 Example New Requirements for Ride Through (work in progress)



P1547 Example New Requirements for Ride Through (work in progress)



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P1547 voltage regulation (Work In Progress)

Two performance categories are defined for DERs with voltage regulation capabilities:

a) Category A covers minimum performance capabilities needed for Area EPS voltage regulation and are reasonably attainable by all state-of-the-art DER technologies

b) Category B covers all requirements within Category A and specifies additional requirements to mitigate voltage variations due to resource variability

P1547 Example New Reactive Power Requirements (Work In Progress)

The DER shall be capable of injecting reactive power (over-excited) and absorbing reactive power (under-excited) equal to the minimum reactive power (kVar) corresponding to the value given in Table TBD at all active power output equal to 20% to 100% of nameplate active power rating (kW).

Table TBD – Minimum Reactive Power Injection and Absorption Capability

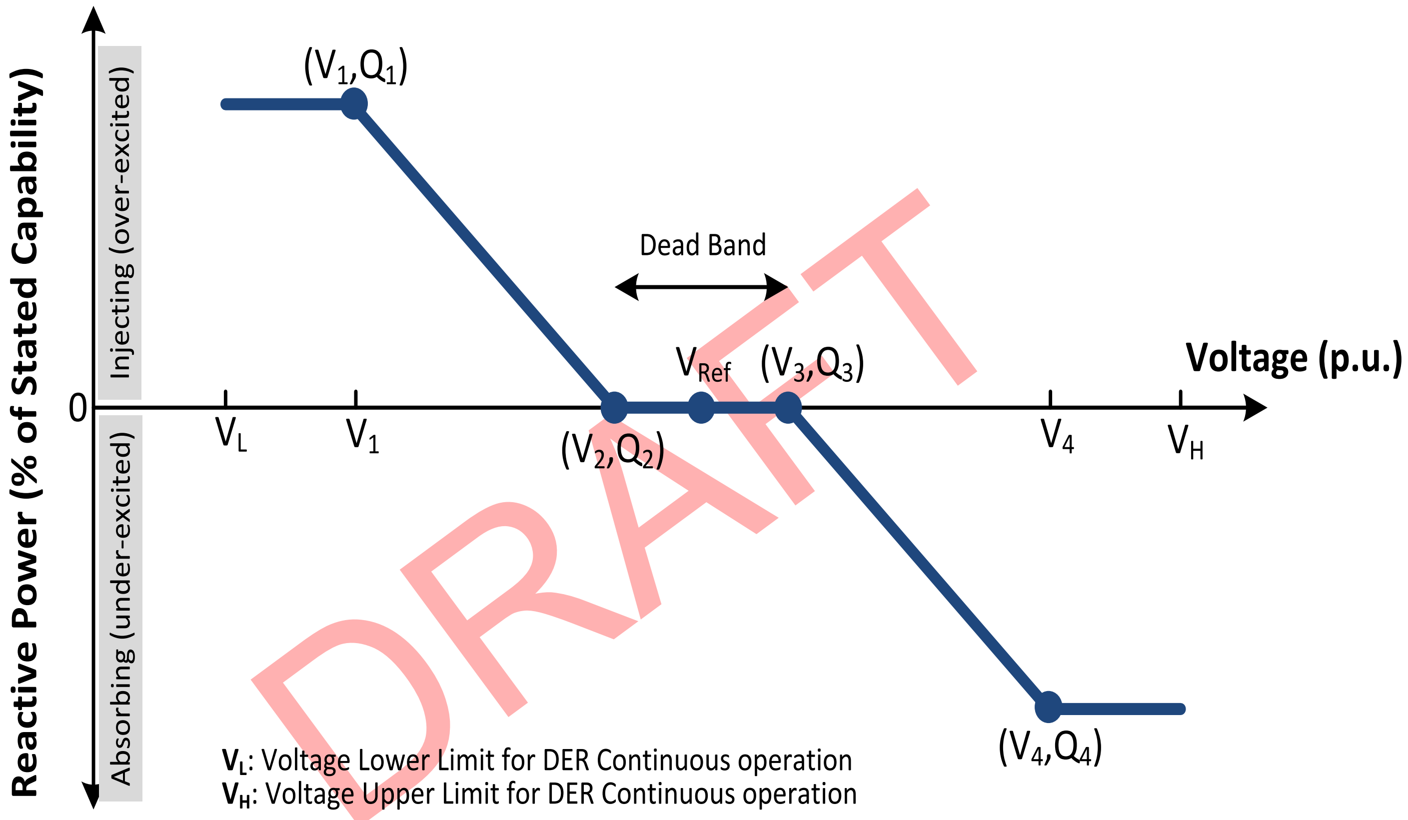
Category	Injection Capability as % of Nameplate Apparent Power (kVA) Rating $Qmin_{inj}$	Absorption Capability as % of Nameplate Apparent Power (kVA) Rating $Qmin_{abs}$
A (at DER rated voltage)	44 Full load PF=0.9	25 Full load PF=0.97
B (at ANSI range A)	44 Full load PF=0.9	44 Full load PF=0.9

Voltage and Reactive Power Control

The DER shall provide the capabilities of the following modes of reactive power control functions:

1. **Adjustable Constant Power factor mode** – The capability is mandatory for categories A and B
2. **Voltage-reactive power (Volt-var) mode** – The capability is mandatory for categories A and B
3. **Active power-reactive power mode (watt-var)** – The capability is optional for category A and mandatory for categories B
4. **Reactive power mode** – The capability is mandatory for categories A and B
5. **Dynamic reactive current**? Still in progress

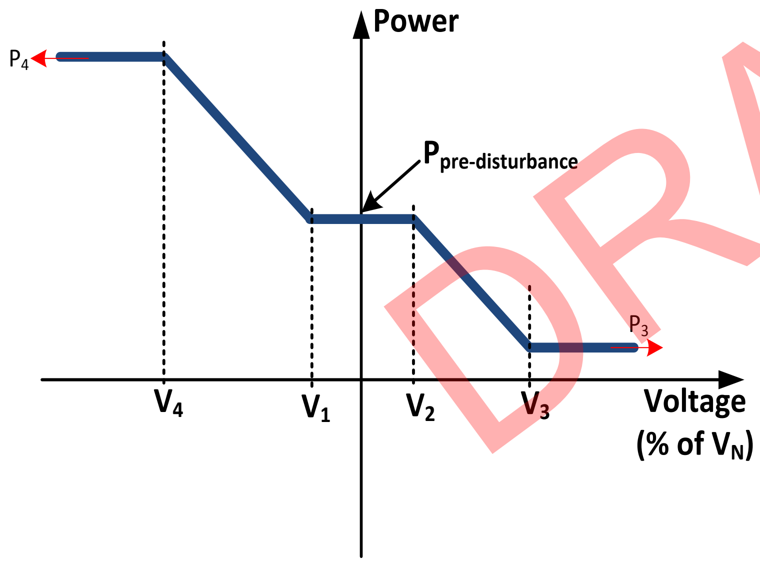
P1547 Example New Reactive Power Requirements (Work In Progress)

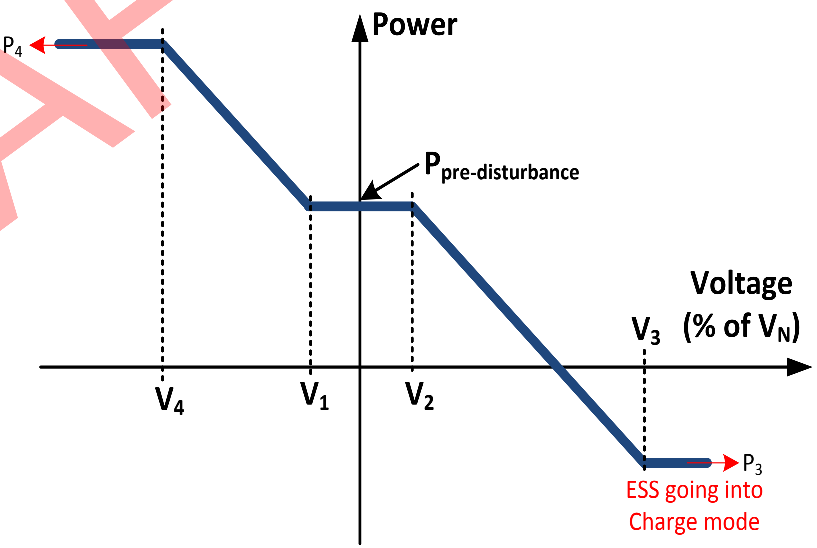


P1547 Example New Voltage Regulation Requirements (Work In Progress)

Voltage-Real Power (Volt-Watt) Mode

When in this mode, the DER shall actively control the real output power as a function of the system voltage following a target voltage – active power (volt-watt) characteristic curve.





Conclusion

- **National Grid is proactively piloting Smart Inverters**
- **Industry standards are being developed/revised to allow utilization of Smart Inverters**
- **MA TSRG is discussing the ways to adopt IEEE 1547**

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Questions?

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